Understanding Intra-response Class Covariation From the Matching Theory Perspective

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Abstract

The purpose of this study was to utilize the matching theory to understand intra-response class covariation as a result of extinction for selected members of the response class versus functional communication training. The participant was a 9-year old girl with a severe disability and problem behaviors. Experimental procedures included functional analysis, extinction, and functional communication training. Results showed that in accordance with the matching theory, responses (problem or adaptive) that were continuously reinforced occurred at a higher rate when compared to responses on extinction. In addition, extinction for some problem responses increased the rate of non-targeted problem responses; however, concurrent reinforcement of a newly learned functionally equivalent communication response increased the rate of this behavior and decreased all problem behaviors.

Keywords: Matching theory, response class, covariation, extinction, functional communication training, developmental disabilities, problem behavior.

Researchers and practitioners continue to be fascinated with understanding and analyzing operant behavior patterns to facilitate the development of enduring behavior support strategies. Toward that goal, the matching theory continues to serve as a foundation for furthering our understanding of the causes of socially mediated behavior specifically for individuals with disabilities and/or behavior disorders. Herrnstein (1970) describes the matching law as a mathematical means for elucidating how behavior responds to concurrent schedules of reinforcement. Stated simply, responses that are consequated with a higher number of reinforcers occur at higher rates than responses that are reinforced at lower (or zero) rates. Both rational and irrational behavior has been explained using the matching theory (Borrero & Vollmer, 2002; Bulow & Meller, 1998; Shriver & Kramer, 1997; Skinner & Robinson, 1996). The basic assumption is that response allocation of operant behavior is a matter of choice.

A choice of any topography over the others at a given point in time is possible only when multiple responses are involved, all of which produce the same functional effect. The literature has described this pattern as a functional response class (Lalli, Mace, Wohn, & Livezy, 1995; Shukla & Albin, 1996; Shukla-Mehta & Albin, 2003; Sprague & Horner, 1992). The concept of response classes is not novel. Still, researchers and practitioners continue to focus attention on understanding what governs choice or the allocation of specific topographies from a class of responses. Such interest has been generated due to observed covariation as a function of concurrently varying rates of reinforcement for the different topographies within a response class (Magee & Ellis, 2000; Parrish, Cataldo, Kolko, Neef, & Egel, 1986). In addition, there has been an observed philosophical shift in the field from the use of decelerative techniques alone in favor of strategies that also lead to increases in adaptive behavior (Carr, Coriaty, & Dozier, 2000; Carr & Durand, 1985; Day, Horner, & O'Neill, 1994; Dunlap, et al, 1995; Horner & Carr, 1997; Horner, Sprague, O'Brien, & Heathfield, 1990; Sugai et al., 2000).

With the advent of hypotheses-based interventions and the focus on identification of multiple topographies within a functional response class, application of the matching theory to understand behavioral allocation has gained momentum. If some topographies within a response class are consequated with a richer schedule of reinforcement (positive or negative), these will occur at higher rates. Our clinical experiences show that more severe topographies of problem behaviors usually lead to a functional reinforcer, example, escape from non-preferred tasks, attention form others, access to tangible objects, and/or sensory reinforcement. Less severe topographies of problem behavior tend to be inadvertently ignored or systematically placed on extinction (which technically means no delivery of a

functional reinforcer). From the matching theory perspective, if less severe topographies from a functional response class are placed on extinction, other, perhaps more severe topographies of problem behavior will occur at higher rates, especially if they successfully produce a functional reinforcer. Therefore, it appears to be more logical to add a functionally equivalent response to the existing class of responses that would produce the same functional reinforcer, yet, be socially appropriate in nature (Day, Horner, & O'Neill, 1994; Durand, & Carr, 1992; Lalli, Casey, & Kates, 1995; Shukla & Albin, 1996; Shukla-Mehta & Albin, 2003; Sprague & Horner, 1992).

The matching theory is a useful heuristic for understanding laws that govern human behavior. This purpose of this study was to assess intra-response class covariation as a function of implementation of (a) continuous reinforcement versus extinction for one or more problem behaviors within a response class, and (b) functional communication training concurrently with extinction on the rate of occurrence of both problem and adaptive responses within the response class.

Method

Participant and Setting

Hanna was 9 years old at the time of the study. She was labeled as having severe to profound mental retardation. She also received medication for seizure control. Hanna used verbal language but her speech was mostly unintelligible even in her native language. Hanna was selected to participate in this study because she displayed severe problem behaviors included piercing screaming, throwing/kicking objects, and arching head/body backwards. All direct observations, functional assessment and intervention procedures were conducted in the participant's home environment.

Measurement

Equipment. A direct-videotaped observation of student and instructor behaviors was conducted. Video data were directly coded on a PC using a software package for simultaneous real-time recording of multiple behaviors (Portable Computer Systems for Observational Use) (Repp, Harman, Felce, Van Acker, & Karsh, 1989; Repp, Felce, & Karsh, 1991). A keyboard key for each measurement variable was assigned in order to record the rate, frequency, and duration of events.

Measurement variables. The primary dependent measure was the response per minute of problem and communication behaviors for Hanna. Target behaviors included screaming (loud and piercing), throwing/kicking objects (hurling objects across the room), and arching head/body backwards (jerking head or whole body backwards). Other topographies that emerged later include flopping on the floor (sitting down and refusing to get up), and hitting and kicking others (making audible contact with any part of another person's body).

Interobserver agreement. Two undergraduate students received extensive training in data collection and coding activities. One of these students served as a primary coder and another was a reliability coder. Both were naive to the hypotheses of the study. Training was provided by the first author until a criterion of at least 90% overall and at least 80% agreement on each individual behavior was achieved for three consecutive sessions. A tolerance setting of 3 seconds was used to compute reliability, meaning that an agreement was scored if both observers pressed the same key within +/- 3 seconds of each other. Interobserver agreement was computed for 40% of the sessions where the overall agreement across all variables was reported to be 97% (range 60-100).

Assessment of conditional probability. The secondary dependent measures were conditional probabilities computed at lag 1 for the various experimental phases. Video data coded on desktop

computers were analyzed to assess the sequential relationships between variables of interest (Bakeman & Gottman, 1986). The software program called Sequential Data Analysis (SDA) developed by Sprague and Shamee (1992) was used to calculate sequential relationships through computation of conditional probabilities. The SDA program generated conditional probabilities and Z scores (Whitehurst, Fischel, DeBaryshe, Caufield, & Falco, 1986). The Z scores determine the statistical significance of conditional probabilities, when compared to the base rates for each variable. Sequential relationships were assessed between (a) multiple problem behaviors within the response class, and (b) problem and communication behaviors given a specific instructor behavior (e.g., give desired object).

Assessment of response effort and intensity. Indirect measures were used to assess the physical effort involved in performing specific behaviors and their intensity (i.e., impact on others). Perceived response effort and intensity for individual problem and communication behaviors for Hanna were measured on a scale of 1-10. Sixteen experienced special education professionals who were naïve to the purpose of this assessment, observed selected video clips (3-5 second duration each) of the participant performing individual responses from the response class. Three independent samples of each behavior were presented in a random order. Special education professionals first rated and then rank ordered Hanna's these responses on a scale of 1-10, from least to most on perceived physical effort and intensity. These ratings and rankings were compiled to analyze the relation between perceived response effort and intensity, and the observed hierarchy of responses in a response sequence.

Design and Procedures

An Alternating Treatment design (Iwata, Dorsey, Slifer, Bauman, & Richman, 1982; Northup et al., 1991; Steege, Wacker, Berg, Cigrand, & Cooper, 1989) was used to document the result of functional analysis of problem behavior. An ABAB'CDC design was used was used to document the effect of implementation of continuous reinforcement (CRF) for all responses, extinction (EXT) for selected responses, and functional communication training (FCT) (Barlow & Hersen, 1987). Procedures for each are described below.

Initial functional assessment interviews and observations were conducted to obtain preliminary information regarding the events and conditions that maintained problem behaviors for Hanna (O'Neill, Horner, Albin, Storey, & Sprague, 1990). Descriptive data indicated that Hanna engaged in multiple topographies of problem behaviors that appeared to be maintained by access to preferred objects, escape from task demands, and access to social attention from adults. Observations also indicated that when task demands were presented, Hanna's problem behavior escalated when she was unable to access task materials and/or objects like magazines, being able to hold a book herself instead of an adult reading the book to her and working with a preferred person. The focus of this study was to intervene in the Tangible context where problem behaviors were maintained by positive reinforcement (access to desired objects).

Functional Analysis. An experimental analysis of problem behaviors was conducted to isolate maintaining variables and to verify multiple topographies that formed a single or multiple functional response classes (Iwata et al., 1982; O'Neill et al., 1990). Procedures for Hanna included 5-min sessions across 4 different conditions, i.e., Demand, Tangible, Attention, and Play. During these procedures, each occurrence of problem behavior was functionally reinforced with escape, access to desired objects, and attention respectively. Any occurrence of problem behavior during Play was ignored.

Extinction. An EXT procedure was implemented using an ABAB' design for Hanna using strategies recommended by Iwata, Pace, Cowdery, and Miltenberger (1994). Phase A (Baseline) represented continuous reinforcement (CRF) for all (problem) behaviors. During Phase B, a single behavior (i.e., screaming) was placed on extinction while all other problem behaviors were maintained on a CRF schedule via access to preferred objects. The purpose was to document the effect of putting the

most frequently occurring behavior on EXT. This condition was followed by a reversal to the CRF schedule. This phase was followed by implementation of EXT for throwing objects (phase B') while other problem behaviors including screaming were maintained on a CRF schedule. In accordance with the matching theory, it was hypothesized that responses placed on EXT (which technically means no delivery of reinforcement) would occur at a lower rate when compared to the base rate for these responses or other responses that were on concurrently on a CRF schedule.

Functional Communication Training. An experimental analysis of functional communication training (FCT) was conducted demonstrate (a) the effectiveness of FCT in decreasing or eliminating problem behaviors, and (b) the pattern of intra-response class covariation as a function of addition of a new, functionally equivalent response to the extinction process. Analysis of FCT (phase C) was documented across three phases following the extinction analysis. Hanna was taught to verbally ask for preferred objects ("I want ...") in her native language. Training for the new response followed similar procedures as documented in the existing literature for FCT and the matching theory (Bird, Dores, Moniz, & Robinson, 1989; Carr & Durand, 1985; Jayne, Schloss, Alper, & Menscher, 1994; Wacker et al., 1990). This phase (D) was followed by concurrent implementation of EXT (communication) and CRF (problem behaviors). The study ended with a reversal to CRF for all communication responses (phase C). It was hypothesized that a CRF schedule for a functionally equivalent response would increase its rate when compared to responses concurrently on EXT.

Results

Visual Analysis of Data

Functional Analysis. Functional analysis data for Hanna are presented in Figure 1. Data indicated the highest rate of problem behaviors for Tangible (*M* = 2.3, range = 1.2-3.6 per minute) followed by Demand (*M* = 1.7, range = 0.8-3.4) and Attention (*M* = 1.2, range = 0.0-5.0) where three of the five sessions showed zero rates. Data showed fairly low rates of problem behaviors in the Play condition (*M* = 0.3, range = 0.0-0.9 per minute). The different topographies of problem behaviors observed in the Tangible condition included screaming, throwing/kicking objects, and arching backwards. No adaptive behavior was observed.

Overall, data from functional analyses for Hanna supported the hypothesis that problem behaviors were positively reinforced by access to tangible objects and negatively reinforced by escape from task demands. Because inability to access tangible objects appeared to be of greater concern for parents, it was determined that subsequent experimental procedures related to this function would be addressed.

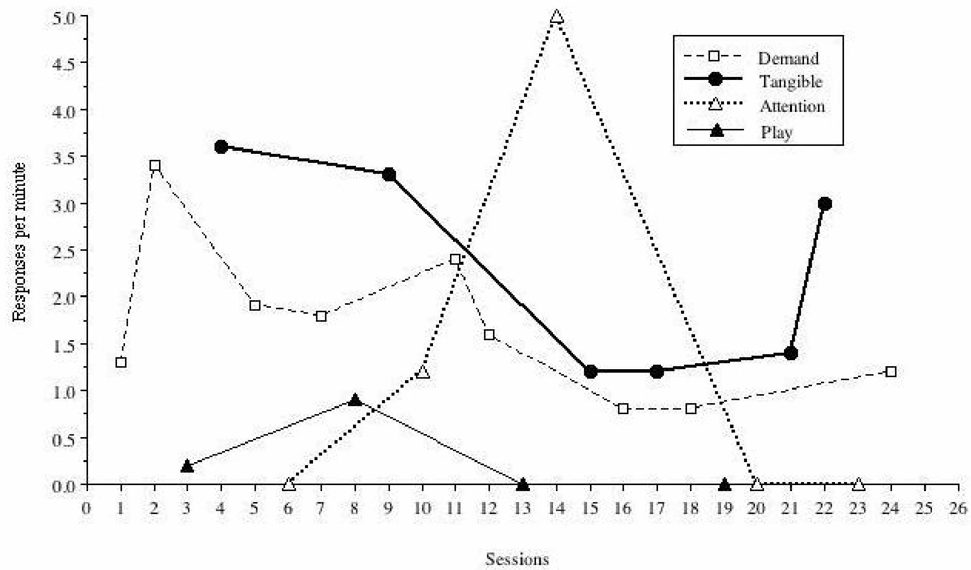

Figure 1. RPM of total problem behaivors for Hanna during Functional Analysis.

<u>Extinction</u>: Data are presented in the ABAB' portion (first four panels) of the design in Figure 2. Data for the first CRF condition (Baseline, phase A) indicated that when all problem behaviors were on a CRF schedule, they occurred at the mean rate of 2.3 per minute (range = 0.3-3.2). Of the total problem behaviors, screaming occurred at the highest rate per minute (*M* = 1.2, range = 0.4-3.1) (charted separately in Phase A). Figure 3 shows the mean rate for individual responses across the different experimental phases. Other problem behaviors included throwing objects (*M* = 0.7, range = 0.0-2.6), arching backwards (*M* = 0.3, range = 0.0-0.6), and walking away (*M* = 0.1, range = 0.0-0.4). Data indicated a pattern of intra-response covariation where early responses (e.g., screaming or throwing) occurred at a higher rate because of contingent reinforcement.

The next phase involved EXT for screaming while all other responses were maintained on the CRF schedule. The purpose was to document the effect of putting the most frequently occurring behavior on EXT. Results showed that while the mean rate of screaming slightly decreased from 1.2 pm to 1.0 pm (range = 0.0-2.3), no dramatic effects or changes were observed as a result of EXT. However, the mean rate of other problem behaviors which were on a CRF schedule, showed an increase including throwing/kicking objects (*M* = 1.0, range = 0.2-1.6), and arching backwards (*M* = 0.8, range = 0.0-1.6). It is interesting to note, however, that as a function of implementation of EXT for one response, two new responses emerged during this condition, namely, flopping on floor (*M* = 0.1, range = 0.0-0.2) and hitting instructor (*M* = 0.1, range = 0.0-0.2) even though the mean rates were low (see Figure 3). Another outcome was that EXT for screaming was that this response started to co-occur with other topographies of the same response class, example, throwing objects and arching backwards.

A reversal to CRF (all responses) showed a high variability in the rate of individual responses (see Figure 2). Throwing/kicking objects occurred at the highest rate during this phase (see Figure 3). This response was placed on extinction during the following phase (B'). Results showed a dramatic decrease in the mean rate for that response, reducing from 1.5 pm in the previous phase to 0.4 per minute. However, when compared to the previous phase, screaming and walking away occurred at a higher rate per minute (see Figure 3). Decrease in throwing/kicking objects may be because (a) the extinction contingency was in effect for each occurrence regardless of whether it occurred by itself or co-occurred

with other responses, and (b) other problem behaviors inadvertently got extinguished when they co-occurred with throw/kick, e.g., screaming.

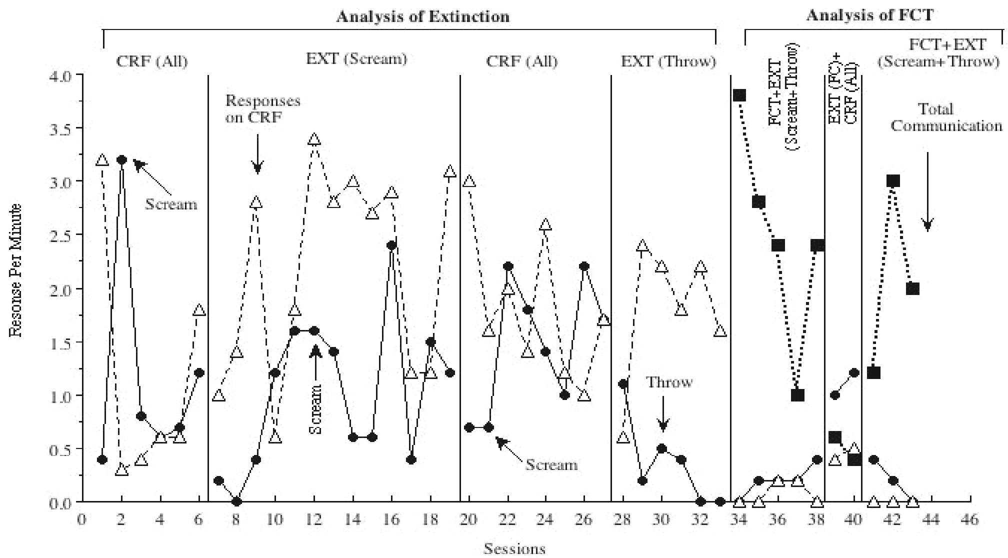

Figure 2. Response per minute of total problem behaviors and total communication versus behaviors on Extinction for Hanna.

To summarize, the first four experimental phases (ABAB') for Hanna showed that responses on a CRF schedule occurred at higher rates whereas responses on EXT occurred at a relatively lower rate. Implementation of EXT also produced new topographies of problem behavior and screaming started to co-occur with other responses. From the perspective of the matching law, if problem behavior is more likely to occur until a functional reinforcer is produced, it appears to be more logical to add a functionally equivalent response to the existing class of responses that would produce the same functional reinforcer, yet, be socially appropriate in nature.

Functional Communication Training: Data for functional communication training (FCT) concurrent with EXT for screaming and throwing (CDC phases in Figure 2) showed an immediate increase in both prompted (1.3 per minute) and unprompted (1.2 per minute) communication, and a dramatic decrease in the mean rate for total problem behaviors (from 2.2 to 0.2 per minute) (See Figures 2 and 3). Throughout FCT, the mean rate for total (prompted and unprompted) communication was as high (2.5) as total problem behaviors (2.7 per minute) during CRF (All) and EXT conditions. Interestingly, while responses on EXT (throw/kick and scream) occurred at a lower rate, zero rates were observed for other problem behaviors on a CRF schedule. Overall data for this phase showed support for the matching theory, demonstrating increases in communication responses as a function of CRF for these behaviors.

FCT was followed by an EXT for communication and CRF for all problem behaviors. Data for this phase need to be treated with some caution because effect was documented only for two sessions due to ethical considerations. Data indicated a decreasing trend for UC demonstrating the effect of EXT. As a result of the CRF schedule, problem behavior showed an increasing trend (Figure 2). A reversal to CRF (UC/PC) and EXT (throw/scream) showed an increase in mean rate for UC (*M* = 1.4, range = 0.6-2.2) and PC (*M* = 0.7, range = 0.6-0.8). Problem behaviors decreased in mean rate from 1.4 in the previous phase to 0.2. Both throw/kick and screaming showed zero rates for the last session and UC showed a reasonably high rate (1.4). As before, since the initiation of FCT, zero rates were also observed for arching backwards, hitting instructor, walking away, and flopping on floor (see Figure 3).

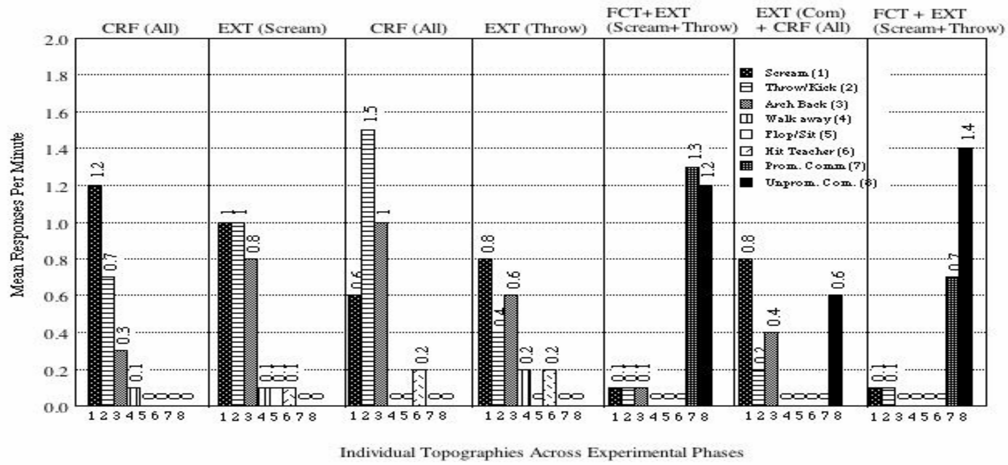

Figure 3. Mean rate of individual topographies across the experimental phases for Hanna.

A summary of results of functional communication training for Hanna combined with extinction for two problem behaviors from the response class showed that (a) a functionally equivalent communication response successfully competed with and replaced or decreased problem behaviors, and (b) Intra-response class covariation as a function of CRF for communication and EXT for problem behaviors was more successful in managing severe problem behavior.

Assessment of Conditional Probabilities

As noted earlier, conditional probabilities (CP) were computed at lag 1 to assess the sequential relationship between (a) individual problem behaviors, responses on EXT, and communication responses within a response class maintained by access to tangible objects, and (b) problem and communication behaviors given a specific instructor behavior (e.g., give desired object). The data are presented in Tables 1 through 4. When all problem behaviors were on a CRF schedule, the CP of screaming given flopping was 50% and given arching backwards, the CP of walking away was 25% (see Table 1).

Table 1
Lag 1 Conditional Probability of Individual Problem Behaviors for Hanna given CRF (All Responses)

Behaviors	Scream	Throw	Arch Back	Walk	Flop	Hit
Scream	0.03	0.02	0.10	0.0	0.0	0.0
Throw	0.12	0.37	0.01	0.0	0.0	0.0
Arch Back	0.09	0.03	0.02	0.25**	0.0	0.0

Walk Away	0.0	0.0	0.50	0.0	0.0	0.0
Flop on Floor	0.50**	0.0	0.0	0.0	0.0	0.0
Hit Instructor	0.0	0.0	0.0	0.0	0.0	0.0

**p<.01

When screaming was placed on EXT (see Table 2), the CP of other behaviors given screaming was 47%. When throwing objects was placed on EXT (see Table 3), given throwing objects, the CP of another throw was 42%. Data also showed that given other problem behaviors not on EXT, the CP of occurrence of any of these behaviors was 93%. When FCT was implemented, the CP of communication given hitting instructor was 100% even though communication was not prompted whereas hitting was reinforced with a tangible item (see Table 4). The CP of screaming following the first scream was 20%.

Table 2
Lag 1 CP of Screaming versus other Problem Behaviors during EXT (Scream)

Behaviors	Scream	Other
Scream	0.38	0.47*
Other	0.07	0.93

**p<.05. **p<10. ***p<001

Table 3
Lag 1 CP of Throwing versus Other Problem Behaviors given EXT (Throw)

Behavior	Throw	Other
Throw	0.42***	0.16
Other	0.20	0.93*

**p<.05. **p<10. ***p<001

Table 4
Lag 1 CP of Communication versus Problem Behaviors given FCT+EXT (Scream & Throw) and for EXT (FC) + CRF (All Responses)

FCT+EXT (Throw & Scream)					
Behavior	Communication	Scream	Throw	Arch Back	Hit
Communication	0.31	0.0	0.0	0.0	0.0
Scream	0.20	0.20**	0.02	0.10	0.0
Throw	0.0	0.0	0.37	0.01	0.0
Arch Back	0.0	0.0	0.03	0.02	0.0
Hit Instructor	1.0*	0.0	0.0	0.0	0.0

EXT (FC) + CRF (All Responses)				
Behavior	Communication	Scream	Throw	Arch Back
Communication	0.31	0.0	0.0	0.0
Scream	0.20	0.20**	0.02	0.10
Throw	0.0	0.0	0.37	0.01
Arch Back	0.0	0.0	0.03	0.02

**p<.05. **p<10. ***p<001

Data that address the hypothesis regarding the relationship between Hanna's and instructor behavior (e.g., give tangible object) are presented in Table 5. When a tangible object was given for screaming, the CP of screaming 50% during the first CRF phase, whereas the CP of occurrence of other responses was 11%. When screaming was placed on EXT, the CP of throwing was 31%. During the second CRF condition, giving a tangible was more likely to be followed by throwing (49%) and other problem behaviors (34%). The CP of communication responses during FCT was 44%.

Assessment of Response Effort and Intensity

As noted earlier, sixteen special education professionals rated and rank-ordered Hanna's individual topographies on a scale of 1-10 from least to most physical effort and intensity. Rating for physical effort showed the following order from least to most effortful: Saying, "I want..." (1.8), throw objects (2.7), walk away (3.0), flop on the floor (3.3), scream (3.5), arch backwards (3.5), and hit/kick instructor (4.1). Rank ordering of the effortfulness of responses from least to most showed the following

order: Saying, “I want...” (1), walk away (2), throw objects (3), scream (4), flop on the floor (5), arch backwards (6), and hit/kick instructor (7).

A rating of response intensity showed the following order from least to most intense: Saying, “I want...” (1.7), walk away (3.2), throw objects (3.5), flop on the floor (3.5), arch backwards (3.8), hit/kick instructor (4.1) and scream (4.1). Interestingly, the rank order of responses from least to most intense showed an identical order.

Table 5
Lag 1 CP of Communication versus Problem Behaviors given Instructor “Giving Object”

	Communication	Scream	Throw	Other
Phase 1: CRF (All)	0.0	0.50*	0.17	0.11*
Phase 2: EXT (Scream)	0.0	0.27	0.31*	0.29
Phase 3: CRF (All)	0.0	0.14	0.49	0.34*
Phase 4: EXT (Throw)	0.0	0.36***	0.13	0.49*
Phase 5: FCT + EXT (Throw & Scream)	0.44**	0.0	0.12	0.0
Phase 6: EXT (FC) + CRF (All)	0.0	0.0	0.0	0.20
Phase 7: FCT + EXT (Throw & Scream)	0.0	0.0	0.0	0.0

**p<.05. **p<10. ***p<001

Discussion

The purpose of this investigation was to explain intra-response class covariation from the matching theory perspective. Visual and conditional probability data showed that when EXT was applied to some early occurring members of the response class, (a) the same behavior (e.g., screaming) occurred at a higher than baseline rate (i.e., extinction burst) or co-occurred with other problem behaviors, and (b) new topographies of problem behaviors emerged even though others members of the class were reinforced (i.e., allocation of new responses to the existing class). Similar results were noted in a study involving two students with disabilities (Magee & Ellis, 2000). The authors placed one less severe but more frequent problem behavior on extinction. As a result, the behavior on extinction decreased but other more severe problem behaviors which were not on extinction (e.g., object destruction for one student and aggression for another) increased in occurrence.

It is this reason that addition of a functionally equivalent alternative response to the response class is essential. Research has shown that FCT has been very effective in not only increasing adaptive behavior but concurrently decreasing problem behavior. In fact, some researchers are using FCT as a tool for preventing severe problem behavior (Reeve & Carr, 2000).

One variable that makes functional communication so effective is its relative efficiency. Efficiency is described with respect to the amount of physical effort it takes to produce a response, the schedule and quality of reinforcement, and the latency of effect (Billington & DiTommaso, 2003; Day, Horner, & O'Neill, 1994; Horner & Day, 1991; Horner, Sprague, O'Brien, & Heathfield, 1990). Horner and colleagues have demonstrated that when a functional equivalent response is less effortful, operates on a rich schedule of reinforcement, and/or also provides immediate reinforcement, it successfully competes with problem behavior. From the perspective of the matching theory, as more efficient responses (e.g., functional communication) increase, less efficient responses (e.g., severe problem behavior) decrease.

In this study, the perceived ratings and rankings of response effort and intensity by special education professionals showed screaming as the most intense and effortful response. Screaming also produced an immediate effect through access to a tangible object more often than not due to the impact of the response on others including in contexts outside of the intervention. Thus, if immediacy of effect is critical, then the response would be more likely to occur even if it is physically more effortful. The only other response that competed successfully with problem behavior was functional communication. Again, using the Matching Theory's explanation, because functional communication operated on a CRF schedule, its rate of occurrence increased, whereas the most frequent problem behaviors which were placed on EXT, showed a decreased rate of occurrence. Future research might apply the matching law using the power equation formula to compare conditions for FCT versus EXT to study the effects on response covariation.

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